EXTENSION NOTE
04
MAY 2006

Walt Klenner
Wildlife Habitat Ecologist

Southern Interior Forest Region

Retention Strategies to Maintain Habitat Structure and Wildlife Diversity during the Salvage Harvesting of Mountain Pine Beetle Attack Areas in the Southern Interior Forest Region

ABSTRACT

This document was prepared for information purposes and consideration in the development of within-stand retention practices in salvage blocks following attack by mountain pine beetle (MPB, *Dendroctonus ponderosae*). It outlines some stand-level practices that will help protect and maintain habitat structure and wildlife diversity during large-scale salvage harvesting. Planning for within-stand retention during salvage harvesting will help create conditions that resemble, to a reasonable extent, the spatial, temporal, and structural characteristics of natural disturbances. Some key habitat issues that may need to be considered when planning for retention within the salvage block include retaining mature forest attributes such as large live trees and snags, connectivity and isolation effects, riparian reserves and management zones, prompt access management, and maintaining heterogeneity. The approaches and suggestions outlined in this report have two objectives: to help maintain habitat for a wide range of biota, and to hasten the process of structural succession by providing suitably dispersed mature and late seral forest legacies within a developing early or immature seral stand. Background information from current published literature on the role of structural retention in managed forests is summarized. Some applications of these principles to

BRITISH COLUMBIA

Ministry of Forests and Range
Southern Interior Forest Region
Forest Science Program

conceptual examples are provided, since each operational field application will face specific opportunities and challenges. Suggested stand-level strategies will be most effective if co-ordinated with complementary landscape-level retention, and applied in the context of a full range of resource values.

1 INTRODUCTION

This document was prepared to provide information to forest managers and planners on the retention practices that will help protect and maintain wildlife habitat during large-scale salvage operations in stands attacked by mountain pine beetle (MPB, *Dendroctonus ponderosae*) in the Southern Interior Forest Region (Figure 1). The document is intended to aid in developing salvage harvesting plans within existing Beetle Management Units where salvage, or a combination of salvage and holding strategies, is being applied. In suppression management units, some of the general principles in this document can also be applied to ensure that desirable wildlife habitat conditions are maintained in the long term. This document identifies some retention practices likely to help protect and maintain wildlife habitat. It is intended to complement existing Ministry of Forests and Range guidelines. Complementary approaches and issues to consider in developing salvage harvest plans at the landscape level, and how to identify priority stands for salvage, have been described by Eng (2004), Snetsinger (2005), applicable Ministry of Forests and Range salvage guidelines, and the Cariboo-

FIGURE 1 Landscape view of a severe mountain pine beetle attack.

Chilcotin Land Use Plan Biodiversity Updates (http://ilmbwww.gov.bc.ca/ilmb/lup/lrmp/northern/cclup/biodiv/index.html).

Certain aspects of the current mountain pine beetle attack in the Southern Interior Forest Region have been examined in some detail, including the likely progression of the attack, effects on short- and longer-term timber supply, wood quality issues, and possible effects on hydrology. It appears that there is relatively little that can be done to diminish the extent or severity of the current attack, and given the scale of potential economic losses, salvage harvesting in stands attacked by MPB will continue to be a priority for several years. By itself, the large-scale loss of large areas of live mature timber represents a significant challenge to maintaining habitat for identified species of wildlife and for biodiversity in general. Salvage harvesting is likely to further diminish stand legacies that remained following the MPB attack. Unless retention strategies are adequately developed and applied, undesirable effects on wildlife habitat attributable to salvage activities are likely (Tinker and Knight 2000; Lindenmayer et al. 2004). The current MPB attack is of special concern because the extent and severity of the attack will leave some landscapes with less than 30% mature forest cover. In this context, a "landscape" is taken to be a 5000–20 000 ha or larger planning area that is dominated (e.g., > 75%) by ecosytems with frequent stand-initiating disturbances (NDT3 forest types; B.C. Ministry of Forests and B.C. Ministry of Environment 1995). Existing resource planning designations such as community watersheds or NDT3 zones within landscape units may conveniently delineate such areas. Where mature and late seral forest is not well dispersed across the landscape (e.g., concentrated in one area) or is in short supply, landscape-level retention strategies may need to be complemented by suitable within-stand retention. This will help ensure that salvage-harvested stands provide adequate habitat for species that require some components of mature or old forest structure, or connectivity for species with large spatial habitat requirements.

Historically, natural disturbances were often viewed as catastrophic events or disasters that disrupted the balance of nature and caused widespread and undesirable disruptions to ecosystems. This view has largely been replaced by a more dynamic, non-equilibrium view (Pickett and White 1985; Botkin 1990; Sprugel 1991; Reice 1994) where ecosystems recover from and are likely dependent on many types and spatial scales of disturbance events (Botkin 1990; Pahl-Wostl 1995). Severe disturbances such as the 1980 Mount St. Helens eruption or the 1988 Yellowstone fires were initially viewed as catastrophes. However, subsequent research has shown that despite their severity, post-disturbance successional trajectories are towards the re-establishment of the pre-disturbance vegetation communities (Moral and Wood 1988; Turner et al. 1997). Studies from such highly disturbed areas also clarify the role of post-disturbance stand legacies in shaping the direction and rate of succession (Foster et al. 1998; Turner et al. 1998). In this context, salvage harvesting of naturally disturbed areas may be viewed as a second disturbance with additive effects that may need to be managed carefully to protect ecological values (Lindenmayer et al. 2004; Donato et al. 2006). Romme et al. (1998) noted that very large disturbances may become qualitatively different from smaller disturbances as the severity of the disturbance increases.

Five key issues underlie concerns about salvage harvesting:

1. The immediate and long-term loss of mature forest attributes, including large live trees, large declining or recently dead stems, and snags and downed wood representing a diversity of sizes and decay conditions.
2. Connectivity and isolation effects, such as the loss of connectivity for dispersal by propagules with relatively poor mobility,

or access to suitable habitat by organisms that require hiding or thermal cover.
3. Reduced riparian habitat, or loss of the connectivity function of riparian areas through isolation effects.
4. Increased access for vehicle traffic and direct or indirect survival effects on carnivores and ungulates.
5. Habitat homogenization.

Each of these issues is discussed briefly below along with suggested practices that will help maintain desired conditions for wildlife and biodiversity.

Precise estimates of the amount of retention necessary to maintain wildlife and biodiversity in managed stands are difficult to determine, but the value of structural legacies to a wide range of biota is well established (see Bunnell et al. 2004; Serrouya and D'Eon 2004 for reviews). Many habitat generalists and early seral specialists do not benefit from structural retention (Bunnell et al. 2004), but species that are strongly associated with mature or old forest conditions clearly do. Studies from many different forest ecosystems have consistently demonstrated the value of structural retention in maintaining biotic diversity and functional processes. For species that require mature or late seral conditions, more retention is generally better than less. Large-scale salvage harvesting represents a special challenge because of a lack of clear technical information from previous studies to identify wildlife habitat requirements in salvage areas (Bunnell et al. 2004). To balance timber and non-timber values, large harvest openings designed to address patch size diversity considerations (Klenner 2001) or to salvage timber killed by natural disturbances (e.g., wildfire or insect attack) will likely need to maintain structural attributes that are required by a wide range of organisms.

Natural disturbances are characterized by complexity, not only in the return interval of the disturbance, but also in the amount and dispersion of live and dead structural legacies that remain following the disturbance. Heinrich and Lewis (2005) noted that between 2 and 24% (average 11%) of eight wildfire areas examined in NDT3 forests in the Southern Interior remained relatively undamaged green "fire skips," and this compared well with studies elsewhere in Canada (e.g., Eberhardt and Woodard 1987; Delong and Tanner 1996). As the size of the wildfire disturbance increased, the size range of green residual patches also increased. Large fire skip patches were often associated with riparian features, areas of broadleaf cover, or openings where fire may not burn continuously. Edge complexity and variable levels of green tree survival within fire skips, along with an increase in the amount of area in green fire skip patches in larger wildfires, are recurring themes.

Similar patterns of variable mortality within stands also characterize MPB attack (Table 1). Cole and Amman (1969), Safranyik et al. (1974), Shrimpton and Thomson (1983), and Shore et al. (2000) describe the increased susceptibility of larger and older lodgepole pine stems to mountain pine beetle attack. The level of mortality in stands is highly variable and depends on a number of factors including species composition, basal area, age, stand density, location of the stand, and MPB populations in the surrounding area. Stands with lower basal area and low densities of susceptible lodgepole pine usually experience lower levels of attack. Hence, MPB-related mortality is often lower or more variable in mixed-species stands or in riparian areas (Romme et al. 1986; Stone and Wolfe 1996). Thinning stands attacked by MPB may also reduce the level of mortality in the stand since reducing stem density and basal area appears to diminish subsequent mortality (Mitchell et al. 1983; McGregor et al. 1987).

The strategies suggested in this report to protect and maintain wildlife habitat during mountain pine beetle salvage harvesting may be viewed as one component of a comprehensive, integrated strategy to address timber, biodiversity and wildlife, visual, recreation, insect pest, range, watershed, and

TABLE 1 Some within-stand structures that would likely be created during an MPB attack in a mature lodgepole pine stand, and activities that would help to maintain important aspects of these conditions during salvage harvesting[a]

Structural attribute	Treatment
High density of medium (20–30 cm dbh) and large (> 30 cm dbh) snags	Designate well-dispersed single tree, small group (100–2000 m²) and larger patches (> 0.25 ha) as wildlife tree retention areas
5–50+% medium and large trees left alive, selective Pl mortality	Designate wildlife tree retention (WTR) patches in areas where some medium and large trees are likely to survive
	Identify areas within the block where species composition would allow for partial cutting in one or more subunits of the block
Dispersed snags and live trees	Identify well-dispersed single tree, small group, large patch, and partial retention strategies (< 75% volume removed, with residuals representative of pre-harvest species and diameter profile)
	Keep distances between retention patches (partial cutting, WTR, and partial retention) to < 150 m wherever possible
Early and advanced Pl and non-Pl regeneration in the understorey	Protect advanced regeneration wherever possible
Downed wood widely distributed	Attempt to retain as much large downed wood (> 15 cm and preferably > 30 cm diameter) as possible, especially long pieces, well dispersed across the site
Riparian areas with a higher proportion of large live trees	Develop enhanced riparian reserves or riparian management areas around streams and wetlands using partial cutting, wildlife tree retention, or partial retention practices
Little or no access	Identify opportunities for access management in the retention plan for the block and the landscape in general, and promptly deactivate road systems wherever possible

[a] See Cole and Amman (1969), Safranyik et al. (1974), Mitchell et al. (1983), Shrimpton and Thomson (1983), Romme et al. (1986), McGregor et al. (1987), Stone and Wolfe (1996), Shore et al. (2000).

other resource issues. From the perspective of maintaining habitat for a broad spectrum of plants and animals, MPB salvage areas larger than 40 ha warrant special considerations in addition to standard forest management practices. Plans for large salvage areas may need to consider practices that resemble, to a reasonable extent, the spatial, temporal, and structural characteristics of natural disturbances. This approach will help develop a balance between timber extraction and maintaining some of the structural legacies that reflect the conditions that would have existed after a natural disturbance. Recognizing the conditions that would exist following an MPB attack (e.g., Table 1), and identifying the within-stand opportunities (e.g., sites to establish patch or single-tree retention, riparian reserves, protecting advanced regeneration, areas with significant

non-pine cover, etc.) that can be used as "anchors" (Zielke et al. 2003) around which retention areas are developed, are two pieces of information that will help field staff or planners identify suitable locations for retention.

Two issues to consider when planning for the amount of structural retention in the salvage area include: (1) the size of the opening (Eng 2004; Snetsinger 2005; Table 2), and (2) the landscape context (see above for a suggested working definition of "landscape" in the context of MPB salvage, and Tables 3 and 4). Larger openings, and salvage

TABLE 2 Recommended proportion of stand-level retention based on opening size (Eng 2004; Snetsinger 2005)

Opening size	Percent of opening not harvested/retained
< 50 ha	10
50–250 ha	10–15
250–1000 ha	15–25
> 1000 ha	> 25

TABLE 3 Minimum within-stand retention objectives (% of stand volume retained) to protect wildlife habitat diversity following MPB salvage operations relative to surrounding landscape conditions. To more widely disperse structure across the salvage cutblock, full retention areas (e.g., WTPs, RRZs) may be supplemented with partial retention cutting[a]

		Percent of THLB that will be early seral after projected MPB salvage in the landscape unit		
		< 33%	33–66%	> 66%
Percent of planning area in THLB	< 33%	7	10	16
	33–66%	10	16	20
	> 66%	16	20	25

[a] Estimates are based on general principles of scale and the need to maintain more within-stand structure as the distance from surrounding mature forest increases. Several factors can mitigate the need for increased levels of retention in large openings (e.g., openings with complex outer boundaries, feathered edges, areas of immature forest and/or partial retention within the block boundary, and other features).

TABLE 4 Suggested distances between retention areas > 0.25 ha within large-scale salvage harvest areas relative to surrounding landscape condition[a]

		Percent of THLB that will be early seral after projected MPB salvage in the landscape unit		
		< 33%	33–66%	> 66%
Percent of planning area in THLB	< 33%	< 500 m	< 400 m	< 300 m
	33–66%	< 400 m	< 300 m	< 200 m
	> 66%	< 300 m	< 200 m	< 150 m

[a] Estimates are based on general principles of scale and the need to maintain more within-stand structure as the distance from surrounding mature forest increases. Several factors can mitigate the need for increased levels of retention in large openings (e.g., openings with complex outer boundaries, feathered edges, areas of immature forest and/or partial retention within the block boundary, and other features).

operations that result in little mature and late seral habitat (e.g. < 35%) in the surrounding landscape, generally warrant greater structural retention than would be applied in conventional small dispersed block, green tree harvesting. The greatest need for special management considerations will likely be in salvage operations larger than 100 ha and in those landscapes where much of the mature and late seral forest has been converted to early seral (e.g., < 40 years old) conditions by other natural disturbances or harvesting entries. Situations that likely warrant increased attention to retention practices include:

- There are very large openings exceeding 250 ha.
- Much of the surrounding landscape is commercially viable and accessible (also see Tables 2 and 3).
- A high proportion of the surrounding landscape is currently or will be in early seral condition because of salvage harvest.
- Higher-level plans identify priority species that require mature or old forest conditions.
- Visual management or watershed issues are of concern.

2 MAINTAINING CRITICAL HABITAT FEATURES

2.1 Mature Forest Attributes

Key mature forest attributes that are diminished during extensive salvage operations include large live trees, large declining or recently dead stems, and a diversity of sizes and decay conditions of snags and downed wood (Franklin et al. 2000). These structural elements are critical to many species and, although they are significantly reduced or virtually eliminated by conventional clearcut harvesting systems, a suite of alternative practices is available that will help maintain significant components of these features in managed stands (Franklin et al. 1997; Lindenmayer and Franklin 1997, 2002; Franklin et al. 2000; Franklin et al. 2002; Hartley 2002; Vanha-Majamaa and Jalonen 2002). Such features are used or required by approximately 35–40% of terrestrial forest-dwelling vertebrates (Bunnell et al. 2004) and many other biota. These attributes are most likely to diminish in abundance after clearcut harvesting or where future harvesting entries will disrupt the development of old forest conditions. Zielke et al. (2003) discuss the utility of wildlife tree retention in conventional cutblocks, and much of their rationale and suggestions for implementation are relevant to MPB salvage blocks. Some practices that will help protect and maintain mature forest attributes in the short and mid-term include:

1. Leave single tree and aggregated Wildlife Tree Retention (WTR) areas well-distributed across the cutblock (contrast Figures 2a, b, and c). From inventory maps, aerial photography, field reconnaissance, and other sources, identify areas within the overall salvage boundary that are:

   - within 50 m of riparian areas,
   - terrain slope classes 4 and 5,
   - rocky outcrops and low-productivity sites,
   - non-merchantable timber (e.g., immature and small amounts of broadleaved species), and
   - problem soil types (very wet, dry, or too shallow).

   Although these features often provide specialized and relatively poor habitat for many species, they can be used as anchors (Zielke et al. 2003) around which wildlife tree retention and complementary partial retention patches (see below) can be planned to increase the overall size of the retention area.

2. To complement the habitat in wildlife tree retention and Riparian Reserve Zones (RRZs), identify sites where partial retention harvesting can be applied in specific areas (Figure 2d). Partial retention

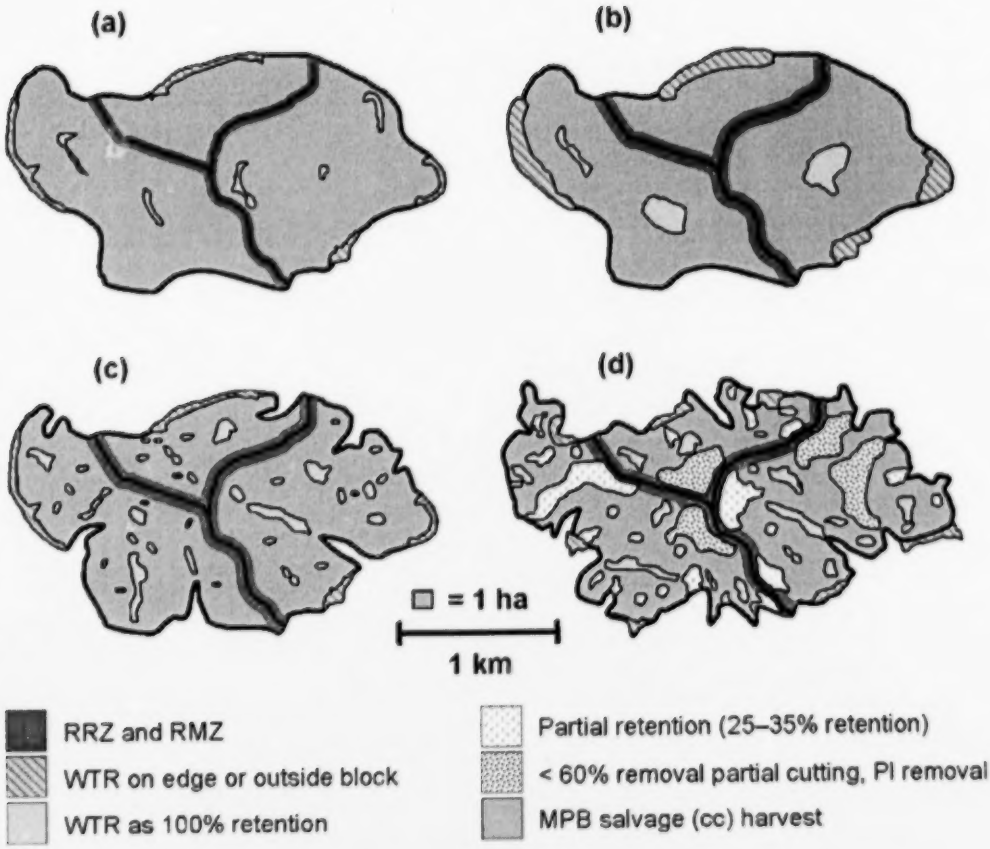

FIGURE 2 Conceptual examples of retention practice options for a large (250 ha) MPB salvage block. (a) Minimum retention practices (e.g., 19 of 250 ha, 7.5%) that leave little structural diversity and few legacies within the clearcut (cc) salvage area to maintain wildlife habitat for species that require mature and old forest structure. (b) Retention practices that leave adequate (e.g., 38 of 250 ha) but widely dispersed structural diversity and legacies in a large MPB salvage area. A greater proportion (15%) of the area has been retained in larger Wildlife Tree Retention areas and Riparian Reserves to maintain wildlife habitat for species that require mature and old forest seral conditions, but large gaps without structure will reduce movement across openings and diminish access to retention areas. (c) Retention practices that use a similar level of retention as in (b) but with improved dispersion to effectively address habitat connectivity. Most retention patches are within 150 m of other retention patches to facilitate movement to and the use of structural attributes in retention areas. (d) A combination of retention, partial retention, and partial cutting has been used to achieve a greater amount (50 of 250 ha, 20%) of well-dispersed structural diversity in a large MPB salvage area. This approach would be especially suitable in areas with concerns about maintaining high-value wildlife habitat, where much of the landscape is in early or immature seral condition, or in subunits of very large salvage openings to provide for a diversity of retention practices.

harvesting is an application of variable retention harvesting (Mitchell and Beese 2002) that maintains a component of the mature green tree and snag structure of the original stand, while up to 75% of the timber can be removed. The residual volume in the areas of partial retention harvesting can be managed similar to that in WTR areas, with further salvage not anticipated except for disease or insect pest control where a compelling case for sanitation can be made. Residual volume can include advanced regeneration, mature stems recently or in the process of being killed by MPB, and some green mature stems (where available) that will remain alive or be recruited as long-term snags and downed wood. Partial retention harvesting will retain a component of the mature stand structure that will help provide:

- habitat and refugia for plants and animals that do not require forest interior conditions,
- cover for animals attempting to cross the clearcut salvage harvest opening,
- hiding cover for species such as large ungulates and carnivores that frequently use early seral habitat, but avoid large openings without cover,
- a seed source or refugium from which plants or animals can colonize the newly developing stand (especially important for organisms such as arboreal lichens that are more likely to colonize new sites through fragments as opposed to propagules),
- irregular edges and diminished contrasts to reduce visual impact (B.C. Ministry of Forests 1994),
- structure to feather or create irregular edges that will help protect (e.g., buffer from windthrow) and enhance the ecological contribution of full retention areas (e.g., WTR, RRZ).

3. Complement the habitat features created with reserves and partial retention harvesting by using partial cut harvesting where the retained stems are likely to persist and maintain or increase their value until the next harvest entry in 25–40 years. This is especially important in salvage blocks > 100 ha, or where numerous salvage blocks coalesce with very early seral habitats (< 20 years old) from previous harvesting to create very large openings approaching or exceeding 250 ha. Strategic placement of partial cutting throughout the landscape can greatly mitigate the visual impact of clearcut salvage harvesting (B.C. Ministry of Forests 1994). Similarly, partial cutting will provide important habitat features within the overall salvage area. For example, identify stand types in the proposed salvage area that have less than 70% mature pine and where partial cut harvesting is feasible. Well-designed partial cut silvicultural systems that are appropriate for the stand type may be promoted where the residual timber has a reasonable likelihood of surviving to the next planned entry (i.e., following green-up on the remainder of the salvage block). Locating these areas near permanent haul roads will diminish access issues in the next entry. Residual trees will maintain some mature forest structure in the salvage area, facilitating animal movement across large openings and providing critical habitat not available in the clearcut areas of the salvage block. Clearcutting these mixed-species stands would represent a sharp departure from the structural conditions that would develop in the absence of salvage harvesting (Table 1). Undesirable consequences of applying clearcut systems on these sites may include lost mid-term harvest or other management opportunities, loss of a source of non-pine regeneration, and increasing homogeneity of the post-harvest landscape.

4. Retain as much downed wood, well dispersed across the site, as is feasible.

Retain non-merchantable snags and green wood, especially large-diameter material, either as standing trees or cut and leave at the stump rather than hauling to cull piles. Complement this with non-merchantable piece sizes and low-quality material (e.g., pulp grades) wherever feasible. Scattered small piles of downed wood (e.g., 10–20 m^3) complement dispersed downed wood by providing subnivian (the relatively open, crystalline layer that forms between the ground surface and snowpack) access points for species such as marten.

5. Establish the landscape context (see Introduction) in which the salvage operation is planned by identifying the proposed size of the salvage harvest block, calculating the timber harvest land base (THLB) proportion of the planning area, calculating the proportion of the THLB area that will be early seral following projected mountain pine beetle salvage harvest, and identifying specific habitat objectives from higher-level plans, if available. This information helps provide criteria for evaluating and establishing stand-level retention targets and approaches (Tables 2-4). In salvage blocks approaching 100 ha or more, consider increasing retention levels (as wildlife tree retention areas and riparian reserves) as outlined in Tables 2 and 3, and consider using partial retention harvesting to increase the area where structure is retained. Partial retention harvesting will provide some structural legacies while allowing for the removal of up to 75% of the merchantable timber.

6. Where harvesting effects on fish-bearing streams or watershed hydrology are of increased concern, suitable machinery can be used to keep ground disturbance to a minimum, and consider harvesting on a snowpack of 50 cm or on frozen ground to minimize disturbance of understorey vegetation and soil.

2.2 Connectivity and Isolation Effects

Large openings without structure represent barriers to dispersing organisims that require hiding or thermal cover, and to species that have propagules with relatively poor mobility. To facilitate the dispersal of organisms across large openings created by salvaging merchantable timber and to facilitate the movement of animals to WTR patches and RRZs, disperse areas of retention, partial retention, and partial cutting across the cutblock.

Figure 2a outlines a conceptual example of a 250 ha MPB salvage block where approximately 7.5% (19 ha) has been reserved in retention patches. This scenario has little area further than 500 m from either a block edge or retention patch, but little connectivity or habitat structure is maintained across the salvage area. Although it represents a "minimum" approach to the maintenance of wildlife habitat in a salvage operation, it may be acceptable in areas where either the majority of the landscape is either inaccessible for harvest or where a relatively small proportion of the landscape will be in early seral condition following projected pine beetle salvage harvest (Tables 3 and 4). Hence, it is important to review the landscape context for the proposed salvage block, and to consider this information to guide salvage and retention planning in that area.

This approach needs to be balanced with the opportunities that exist in the proposed salvage area. For example, although a salvage block may not be in a highly disturbed or accessible landscape, the forest within the proposed block may be especially suitable for a range of harvesting systems and retention practices. By balancing context and opportunities, a diversity of management systems can be applied to avoid creating large areas with homogeneous conditions (see Habitat Homogenization section below).

In situations where much of the landscape is accessible for harvest or will be in early seral condition following projected pine beetle salvage harvest, or where there is heightened

concern over visual, wildlife, watershed, or other values, retaining structure and opportunities for connectivity should likely receive greater emphasis.

Figure 2b represents a scenario where approximately 15% of the salvage area has been retained as large wildlife tree retention patches and enhanced riparian reserve zones. More habitat has been retained than in Figure 2a, but the poorly dispersed retention areas limit the habitat value and effectiveness of this approach. For example, species such as marten (Huggard 1999) seldom forage more than 50 m away from a forest edge and are reluctant to cross large (> 100 m across) openings. Extensive areas without structure remain problematic for such species to cross, and retention areas may receive little use because many species would not cross large openings.

A preferable approach for distributing the 15% retention "budget" is illustrated in Figure 2c, where a similar amount of habitat has been retained but where: (1) retention areas are smaller and more uniformly dispersed, and (2) less area has been retained as WTR on the edge of the block. This helps diminish inter-patch distances (Table 4) and increases access to, and the likelihood of use by, a wider range of biota. The habitat benefits of dispersed retention within cutblocks (e.g., connectivity, recolonization sources, heterogeneity, diminished line of sight, interspersion of mature attributes with developing early seral conditions) outweigh the benefits of aggregated retention (Figure 2b, interior conditions within retention areas) since even relatively large retention patches contain little habitat more than 100 m from the patch edge. Landscape retention practices (e.g., long-term retention, old-growth management areas [OGMAs], ecological reserves, Protected Areas) are better suited to maintaining mature forest interior conditions.

Another option, representing somewhat higher levels of retention (20%) and a combination of clearcutting, partial cutting, and partial retention, is presented in Figure 2d. Partial cutting and partial retention areas have been designed to complement the habitat structure in full retention areas to improve connectivity and to provide dispersed structural retention across a greater proportion of the salvage harvest openings. This scenario may be considered for application:

- in very large openings (> 250 ha, Table 2),
- in subunits within large salvage harvest areas (e.g., to promote a diversity of retention practices),
- where the landscape context warrants greater emphasis on within-block structure (Table 3),
- where higher-level plans or guidelines emphasize maintaining mature and late seral-dependent species, or
- where identified species or general biodiversity considerations warrant increased emphasis on dispersed structure.

The practices illustrated in Figures 2c and d also represent useful approaches to mitigate visual impacts and to complement practices that address watershed management concerns. Some examples of current retention practices in conventional and salvage harvest applications are illustrated in Figure 3.

2.3 Riparian Reserves and Management Zones

Enhancing retention in and adjacent to riparian areas is a key method of maintaining wildlife habitat values in the salvage area (Bunnell et al. 2004) and needs to be developed in co-ordination with the overall retention design for the block. Figure 2d represents such a condition, and components of this design can readily be adapted to conditions illustrated in Figures 2a–c. Wider riparian reserves and management zones, coupled with well-dispersed full and partial retention patches across the cutblock, will help ensure that habitat structures are available and accessible. The width of riparian

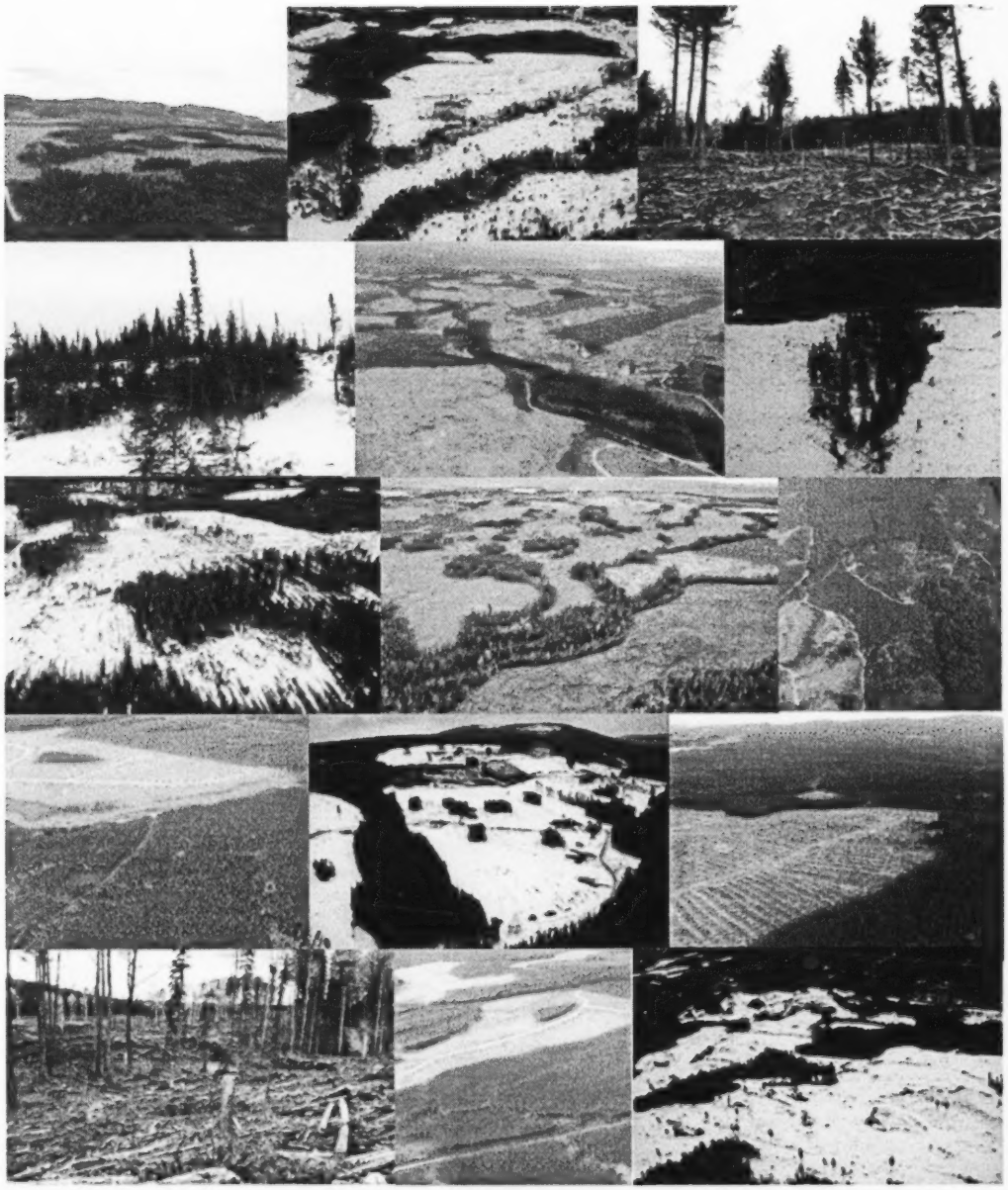

FIGURE 3 Some examples of existing retention practices for salvage or green-tree harvesting in mountain pine beetle–affected stands.

reserve zones may be increased and excluded from salvage harvesting, except in special circumstances where there is a clear risk of fallen trees blocking the stream and altering channel morphology. Opportunities for partial cut or partial retention harvesting in riparian management zones may be identified to help complement the habitat value of the relatively narrow riparian reserve zone. For example, partial cut or partial retention harvesting in riparian management areas around reserves, along stream types that do not require reserves (e.g., S6), on unclassified feeder streams, or around wetlands and stream confluences will diminish sedimentation and stream warming. Retain large green trees, when available, especially on relatively well drained areas with lower windthrow risk.

2.4 Increased Access and Associated Direct or Indirect Effects

Both established roads and new roads built to access salvage areas can affect habitat quality and may exacerbate stream sedimentation, causing undesirable effects on aquatic biota (Forman and Alexander 1998; Forman et al. 2003). These effects can be reduced by keeping new roads to a minimum and deactivating existing or new roads as soon as possible following the completion of silvicultural obligations. Access management issues may need to be reviewed for each salvage block in the context of adjacent or projected blocks as the salvage operation expands. Special road deactivation or access management practices may need to be implemented in wildlife habitat areas or in designated wildlife areas where special habitat management guidelines are in effect (e.g., mule deer, elk, mountain caribou, grizzly bear, or lakeshore/wetland management areas).

2.5 Habitat Homogenization

One of the key principles of managing habitats to maintain biodiversity is to maintain heterogeneity at different scales (Lindenmayer and Franklin 2002). Natural disturbances play a key role in this regard (Pickett and White 1985), disrupting succession and creating a mosaic of conditions at a wide range of scales from the individual tree and stand, to the sub-regional scale of several hundred thousand hectares or more. Key characteristics of natural disturbance are variability in the intensity, frequency, duration, and severity of the disturbance (Romme et al. 1986; Eberhart and Woodard 1987; Delong and Tanner 1996; Stone and Wolf 1996; Turner et al. 1998). However, unless carefully addressed, this variability can be lost through poorly planned salvage harvesting (Lindenmeyer et al. 2004). Practices that will help maintain habitat variability include:

- Identify opportunities for implementing different harvest systems to create variability in the tree species mix, and the types and amount of structural legacies that will exist in the post-salvage stand, utilizing clearcut, clearcut with retention, partial cut, and partial retention systems,
- Attempt to maintain patch size diversity by planning for a mix of small (< 40 ha), medium (40–100 ha), and large (> 100 ha) salvage blocks with edge complexity wherever feasible,
- Avoid implementing the same site preparation and planting prescriptions throughout the salvage area to avoid homogenizing understorey conditions,
- Protect advanced regeneration, and where feasible, plant non-pine species to diminish the likelihood of re-establishing extensive areas (thousands of hectares) strongly dominated by lodgepole pine,
- In blocks > 100 ha, promote genetic variability by using planting stock from two or more seed orchards,
- Record the objectives and range of treatments applied to the salvage area to facilitate tracking the diversity of treatments across multiple salvage areas and to enable future evaluation of the efficacy of the treatments.

3 ACKNOWLEDGEMENTS

I thank H. Armleder, A. Arsenault, M. Burwash, M. Eng, D. Huggard, H. Jennings, L. Laithwaite, D. Lewis, P. Rennie, C. Ritchie, R. Smith, K. Soneff, R. Walton, R. Winkler, and K. Zielke for helpful and insightful review comments on an earlier draft of this document. H. Armleder, K. Buxton, L. Maclauchlan, R. Smith, and R. Toperczer generously provided photos of examples of current retention practices.

4 REFERENCES

B.C. Ministry of Forests. 1994. Visual landscape design training manual. Victoria, B.C. 166 pp.

B.C. Ministry of Forests and B.C. Ministry of Environment. 1995. Biodiversity guidebook. Forest Practices Code of B.C. Victoria, B.C. 95 pp.

Botkin, D.B. 1990. Discordant harmonies: a new ecology for the twenty-first century. Oxford University Press, New York, N.Y. 241 pp.

Bunnell, F.L., K.A. Squires, and I. Houde. 2004. Evaluating the effects of large-scale salvage logging for mountain pine beetle on terrestrial and aquatic vertebrates. Natural Resour. Can., Can. For. Serv., Pac. For. Centre, Victoria, B.C. Mountain Pine Beetle Initiative Working Paper 2004-2. 57 pp.

Cole, W.E. and G.D. Amman. 1969. Mountain pine beetle infestations in relation to lodgepole pine diameters. U.S. Dep. Agric., For. Serv., Intermountain For. and Range Exper. Sta., Ogden, Utah. Res. Note INT-95. 7 pp.

Delong, C. and D. Tanner. 1996. Managing the pattern of forest harvest: lessons from wildfire. Biodiv. Cons. 5:1191-1205.

Donato, D.C., J.B. Fontaine, J.L. Campbell, W.D. Robinson, J.B. Kauffman, and B.E. Law. 2006. Post-wildfire logging hinders regeneration and increases fire risk. Science 311:352.

Eberhart, K.E. and P.M. Woodard. 1987. Distribution of residual vegetation associated with large fires in Alberta. Can. J. For. Res. 17:1207-1212.

Eng, M. 2004. Forest stewardship in the context of large scale salvage operations: an interpretation paper. B.C. Min. For., Res. Br., Victoria B.C. Tech. Rep. 019. http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr019.htm

Forman, R.T.T. and L. Alexander. 1998. Roads and their major ecological effects. Ann. Rev. Ecol. Syst. 29:207-231.

Forman, R.T.T., D. Sperling, J.A. Bissonette, A.P. Clevenger, C.D. Cutshall, V.H. Dale, L. Fahrig, R. France, C.R. Goldman, K. Heanue, J.A. Jones, F.J. Swanson, T. Turrentine, and T.C. Winter. 2003. Road ecology: science and solutions. Island Press, Washington, D.C.

Foster, D.R., D.H. Knight, and J.F. Franklin. 1998. Landscape patterns and legacies resulting from large, infrequent forest disturbances. Ecosystems 1:497-510.

Franklin, J.F., D.R. Berg, D.A. Thornburgh, and J.C. Tappeiner. 1997. Alternative silvicultural approaches to timber harvesting: variable retention harvest systems. *In* Creating a forestry for the 21st century. K.A. Kohm and J.F. Franklin (editors). Island Press, Washington, D.C., pp. 111-139.

Franklin, J.F., D. Lindenmayer, J.A. MacMahon, A. McKee, J. Magnuson, D.A. Perry, R. Waide, and D. Foster. 2000. Threads of continuity. Cons. Biol. in Practice 1:8-16.

Franklin, J.F., T.A. Spies, R. Van Pelt, A.B. Carey, D.A. Thornburgh, D.R. Berg, D.B. Lindenmayer, M.E. Harmon, W.S. Keeton, D.C. Shaw, K. Bible, and J. Chen. 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. For. Ecol. Manage. 155:399-423.

Hartley, M.J. 2002. Rationale and methods for conserving biodiversity in plantation forests. For. Ecol. Manage. 155:81-95.

Heinrich, R. and D. Lewis. 2005. Analysis of residual forest structure left following

wildfires within the Natural Disturbance Type (NDT) 3 in the Southern Interior of British Columbia: A preliminary review – Draft Report to Weyerhaeuser Canada, Kamloops, B.C. 34 pp.

Huggard, D.J. 1999. Marten use of different harvesting treatments in high-elevation forest at Sicamous Creek. B.C. Min. For., Victoria, B.C. Res. Rep. 17. 17 pp. http://www.for.gov.bc.ca/hfd/pubs/Docs/Rr/Rr17.pdf

Klenner, W. 2001. Guiding principles and issues to consider in the development of aggregated harvest areas. B.C. Min. For., Kamloops Forest Region. Draft report. 24 pp.

Lindenmayer, D.B., D.R. Foster, J.F. Franklin, M.L. Hunter, R.F. Noss, F.A. Schmiegelow, and D. Perry. 2004. Enhanced salvage harvesting policies after natural disturbance. Science 303:1303.

Lindenmayer, D.B. and J.F. Franklin. 1997. Managing stand structure as part of ecologically sustainable forest management in Australian mountain ash forests. Cons. Biol. 11:1053–1068.

———. 2002. Conserving forest biodiversity: a comprehensive, multiscaled approach. Island Press, Washington, D.C.

McGregor, M.D., G.D. Amman, R.F. Schmitz, and R.D. Oakes. 1987. Partial cutting lodgepole pine stands to reduce losses to the mountain pine beetle. Can. J. For. Res. 17:1234–1239.

Mitchell, R.G., R.H. Waring, and G.B. Pitman. 1983. Thinning lodgepole pine increases tree vigor and resistance to mountain pine beetle. For. Sci. 29:204–211.

Mitchell, S.J. and W. Beese. 2002. The retention system: reconciling variable retention with the principles of silvicultural systems. For. Chron. 78:397–403.

Moral, R. del and D. M. Wood. 1988. Dynamics of herbaceous vegetation recovery on Mount St. Helens, Washington, USA, after a volcanic eruption. Plant Ecol. 74:11–27.

Murphy, T.E.L., D.L. Adams, and D.E. Ferguson. 1999. Response of advance lodgepole pine regeneration to overstory removal in eastern Idaho. For. Ecol Manage. 120:235–244.

Pahl-Wostl, C. 1995. The dynamic nature of ecosystems – chaos and order entwined. Wiley, Toronto, Ont.

Pickett, S.T.A. and P.S. White (editors). 1985. The ecology of natural disturbance and patch dynamics. Academic Press, New York, N.Y.

Reice, S.R. 1994. Nonequilibrium determinants of biological community structure. Amer. Scientist 82:424–435.

Romme, W.H., E.H. Everham, L.F. Frelich, M.A. Moritz, and R.E. Sparks. 1998. Are large, infrequent disturbances qualitatively different from small, frequent disturbances? Ecosystems 1:524–534.

Romme, W.H., D.H. Knight, and J.B. Yavitt. 1986. Mountain pine beetle outbreaks in the Rocky Mountains: regulators of primary productivity? Amer. Nat. 127:484–494.

Safranyik, L., D.M. Shrimpton, and H.S. Whitney. 1974. Management of lodgepole pine to reduce losses from the mountain pine beetle. Can. For. Serv., Dep. Environ., Pac. For. Res. Centre, Victoria, B.C. Tech. Rep. 1. 24 pp.

Serrouya, R. and R. D'Eon. 2004. Variable retention forest harvesting: research synthesis and implementation guidelines. Knowledge Exchange and Technology Extension Program (KETE) Sustainable For. Manage. Network, Edmonton, Alta. 43 pp.

Shore, T.L., L. Safranyik, and J.P. Lemieux. 2000. Susceptibility of lodgepole pine stands to the mountain pine beetle: testing of a rating system. Can. J. For. Res. 30:44–49.

Shrimpton, D.M. and A.J. Thomson. 1983. Growth characteristics of lodgepole pine associated with the start of mountain pine beetle outbreaks. Can. J. For. Res. 13:137–144.

Snetsinger, J. 2005. Guidance on landscape- and stand-level structural retention in large-scale mountain pine beetle salvage operations. Victoria, B.C. 8 pp.

http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/stewardship/cf_retention_guidance_dec2005.pdf

Sprugel, D.G. 1991. Disturbance, equilibrium, and environmental variability: what is 'natural' vegetation in a changing environment? Biol. Cons. 58:1–18

Stone, W.E. and M.L. Wolfe. 1996. Response of understory vegetation to variable tree mortality following a mountain pine beetle epidemic in lodgepole pine stands in northern Utah. Plant Ecol. 122:1–12.

Tinker, D.B. and D.H. Knight. 2000. Coarse woody debris following fire and logging in Wyoming lodgepole pine forests. Ecosystems 3:472–483.

Turner, M.G., W. Baker, C.J. Peterson, and R.K. Peet. 1998. Factors influencing succession: lessons from large, infrequent natural disturbances. Ecosystems 1:511–523.

Turner, M.G., W.H. Romme, R.H. Gardner, and W.W. Hargrove. 1997. Effects of fire size and pattern on early succession in Yellowstone National Park. Ecol. Monogr. 67:411–433.

Vanha-Majamaa, I. and J. Jalonen. 2001. Green tree retention in Fennoscandian forestry. Scand. J. For. Res. 3:79–90. (Suppl.)

Zielke, K., B. Bancroft, and D. Farquharson. 2003. Stand level retention strategies for Tolko Industries, Thompson Woodlands. First Approximation Booklet. Tolko Industries Ltd., Heffley Ck. Division.

Citation:
Klenner, W. 2006. Retention strategies to maintain habitat structure and wildlife diversity during the salvage harvesting of mountain pine beetle attack areas in the Southern Interior Forest Region. B.C. Min. For. Range, S. Int. For. Reg., Kamloops, B.C. Exten. Note 04. <http://www.for.gov.bc.ca/hfd/Pubs/RSI/FSP/EN/RSI_EN04.htm>

The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the Government of British Columbia of any product or service to the exclusion of others that may also be suitable. This Extension Note should be regarded as technical background only. Uniform Resource Locators (URLs), addresses, and contact information contained in this document are current at the time of printing unless otherwise noted.